AMP. BUREAU ENTOM.
Recd. 10 MAR. 1913

CONNECTICUT
AGRICULTURAL EXPERIMENT STATION
NEW HAVEN, CONN.

BULLETIN 169, NOVEMBER, 1911.

ENTOMOLOGICAL SERIES, No. 16.

The Leopard Moth

Fig. 1. Female Leopard Moth. Natural size.

CONTENTS.

	Page
Appearance of Infested Trees	3
This Insect a Pest in Europe	4
Occurrence in other Countries	5
History of its Spread in America	5
Distribution and Spread in Connecticut	8
Description	9
Life History and Injury	10
Natural Enemies and Checks	14
Remedial Treatment	15
Bibliography	20
Summary	24

The Bulletins of this Station are mailed free to citizens of Connecticut who apply for them, and to others as far as the editions permit.

CONNECTICUT AGRICULTURAL EXPERIMENT STATION.

OFFICERS AND STAFF.

BOARD OF CONTROL.

His Excellency, SIMEON E. BALDWIN, *ex-officio, President.*
PROF. H. W. CONN, *Vice President*.....Middletown
GEORGE A. HOPSON, *Secretary*.....Wallingford
E. H. JENKINS, *Director and Treasurer*.....New Haven
J. W. ALSOP.....Avon
WILSON H. LEE.....Orange
FRANK H. STADTMUELLER.....Elmwood
JAMES H. WEBB.....Hamden

STATION STAFF.

ADMINISTRATION.
E. H. JENKINS, PH.D., *Director and Treasurer.*
MISS V. E. COLE, *Librarian and Stenographer.*
MISS L. M. BRAUTLECHT, *Bookkeeper and Stenographer.*
WILLIAM VEITCH, *In Charge of Buildings and Grounds.*

CHEMISTRY.
ANALYTICAL LABORATORY.
JOHN PHILLIPS STREET, M.S., *Chemist in Charge.*
E. MONROE BAILEY, PH.D., C. B. MORRISON, B.S.,
R. B. ROE, A.B., C. E. SHEPARD, *Assistants.*
HUGO LANGE, *Laboratory Helper.*
V. L. CHURCHILL, *Sampling Agent.*

PROTEID RESEARCH.
T. B. OSBORNE, PH.D., *Chemist in Charge.*
MISS E. L. FERRY, A.B., *Assistant.*
MISS LUVA FRANCIS, *Stenographer.*

BOTANY.
G. P. CLINTON, S.D., *Botanist.*
E. M. STODDARD, B.S., *Assistant.*
MISS M. H. JAGGER, *Seed Analyst.*
MISS E. B. WHITTLESEY, *Herbarium Assistant.*

ENTOMOLOGY.
W. E. BRITTON, PH.D., *Entomologist; also State Entomologist.*
B. H. WALDEN, B.AGR., D. J. CAFFREY, B.S., *Assistants.*
MISS E. B. WHITTLESEY, *Stenographer.*

FORESTRY.
SAMUEL N. SPRING, M.F., *Forester; also State Forester and State Forest Fire Warden.*
W. O. FILLEY, *Assistant State Forester.*
MISS E. L. AVERY, *Stenographer.*

PLANT BREEDING.
H. K. HAYES, M.S., *Plant Breeder.*
C. D. HUBBELL, *Assistant.*

THE LEOPARD MOTH.

Zeuzera pyrina Linn. (= *æsculi* Linn.)

BY

W. E. Britton, *State Entomologist,*

AND

G. A. Cromie, *Superintendent of Trees in the City of New Haven.*

Appearance of Infested Trees.

Many of the magnificent elms that have stood as landmarks on the streets and in the central parks of New Haven and other coastwise cities of Connecticut for over a century are dying with little outward apparent cause. And not only are the veterans being destroyed, but trees of all ages suffer where apparently receiving sufficient food and moisture. Dead branches may be seen in numbers, standing above the leafy masses in the tree-tops. Each storm brings down numbers of branches, many of them in full leaf, and if the broken ends are examined, one will notice that just underneath the bark the branch has been girdled. This is the work of an insect that has only within the last few years reached Connecticut, but which has already proved itself our most serious insect enemy of shade trees,—the leopard moth.

Trees recently infested show small twigs broken over and wilted, the leaves on the ends of occasional branches turn yellow and in a few weeks drop. Trees in a later stage show a mass of dead upper branches, as is shown on Plate I, while from the trunk and larger limbs sprouts or suckers appear. Here and there branches are seen with comparatively few, small, sickly leaves. Yet when the tree is cut down the trunk and larger limbs have the appearance of perfect health.

Since the larva bores largely in the sapwood and cambium, the damage done by it is unusually severe, the work of one insect often being sufficient to kill a small tree. Remaining in the wood during the greater part of its life, it is rarely seen by the casual observer, and for the same reason no general and convenient

methods of controlling it are available, as in the case of insects which eat the foliage. It does not confine its attacks to elms, but is a very general feeder, being found to some extent on nearly all our deciduous trees and larger shrubs. Like many other insect pests that have at various times become unusually destructive, this leopard moth is not a native of this country, but was introduced here probably from Europe. The number of dead branches caused by it not only threatens the life of the tree, but falling from the height to which some of our large trees have grown, are a source of great danger to property and to persons passing beneath them. In Newark, N. J., scarcely a large tree of species susceptible to attack stands to-day, uninjured by this pest, while numbers of young elms recently planted are being deformed.

In Central Park, New York City, Dr. Southwick "has removed hundreds of loads of branches killed by this insect," while in Cambridge, Mass., numbers of old elms have already been removed from this cause.

In New Haven the damage is especially severe in the older sections of the city, within a radius of one mile from the City Hall. On Central, Wooster and Broadway Greens most of the older trees have either been removed or are badly mutilated by the removal of the dead wood. In other parts of the city the insect is present, but severe damage can be found only in occasional groups of trees. Because the female moth is a poor flyer, a tree (or a group of trees) is liable to be the home of succeeding generations as long as portions of it remain alive, while trees only a short distance away are often free from the pest. The trees of New Haven are at present especially liable to injury because they are large and in long, close rows, with interlacing branches, and of species readily attacked.

This Insect a Pest in Europe.

Though apparently the leopard moth is less serious as a pest of shade trees in Europe than in this country, it nevertheless does considerable damage. Theobald[80] states that it attacks chiefly the cherry, apple, pear and plum in England, but that he has also seen young walnut trees killed by it, and furthermore that "it has been decidedly on the increase in apple trees during the last few years." He also remarks that the leopard moth has

long been known as a borer into the trunks of various trees in England and all over Europe. In addition to the trees just named, Miss Ormerod[73] mentions ash, beech, birch, elm, holly, lime, oak and horse chestnut. Gillanders[78] includes the hawthorn and sycamore among the trees attacked and injured in England. Rev. J. G. Wood[66] many years ago wrote that though the leopard moth infested fruit trees in England, it seemed to do little if any harm to them. Eckstein[72] writes of the leopard moth as also attacking syringa, willow, maple, mountain ash and mistletoe in Germany, in addition to the food plants already mentioned here. Kollar[64] states that in the neighborhood of Vienna the leopard moth injures the trunks of elm, walnut, pear and apple trees. To this list, according to Judeich-Nitsche[70], may be added linden, poplar, cytisus, alder, pomegranate tree, spindle tree (*Euonymus*) and pine.

The leopard moth is figured in Atlas d'Entomologie[75] Forestiere, plate 29, by E. Henry.

The foregoing references have been cited here to show that the insect is a recognized pest of trees in Europe, although Dr. L. O. Howard, who has made several trips through Europe, states in a letter that the insect does not seem to be especially destructive in any part of Europe which he has visited.

Occurrence in Other Countries.

Though the leopard moth is found throughout Central and Southern Europe, according to the Bureau of Entomology[56] it also occurs in Asia Minor, Northern Morocco, Algeria and Southwestern Africa. Mr. South[81] states that it is also present in Corea and Japan.

According to P. Lesne,[79] this insect is the worst pest of the cork oak in Algeria, though after three years work he claims[84] to have brought it under control by the use of carbon disulphide squirted into the galleries, or better yet, placed in gelatine capsules small enough to be inserted in the burrows. The moisture in the wood dissolves the gelatine in twenty-four hours, and the fumes then kill the borers.

History of its Spread in America.

The leopard moth occurs in Europe, and is believed to have been introduced from there into the United States, though the

date of its introduction is uncertain. The species is included by Walker in his list of Lepidoptera in the British Museum,[65] as occurring in North America, and by John G. Morris in his Synopsis of the Described Lepidotera of North America,[1] with a brief description, and the locality given as "North America." Two years later (1864) the late Professor A. S. Packard, in his Synopsis of the Bombycidae of the United States[2] also includes *Zeuzera pyrina* with the same statement as occurs in the Morris catalogue, from which it may have been copied. *Zeuzera pyrina* may also be found in the list (page 10) of North American Lepidoptera, published by the Brooklyn Entomological Society in 1881.

Professor John B. Smith,[14] however, doubts the identity of the species listed as *Z. pyrina* in Walker's catalogue, which Morris, and probably Packard, had followed. Smith visited the British Museum and was unable to find any specimens or records[18] there to warrant Walker's citation that *Z. pyrina* occurred in North America at the time his catalogue was issued.

The first definite record of the occurrence of the leopard moth in America is a short note by Mr. Jacob Doll in Papilio,[3] which states: "A fine example of this well-known European species was taken in a spider's web in Hoboken, N. J., in June, last, by Mr. Schmitz. It was alive and was endeavoring to escape from the web. The specimen is now in the collection of Mr. B. Neumoegen." This was written in 1882, and the moth taken in 1881.

Entomological News for March, 1904,[46] states that this specimen was a female, and was captured in 1879 instead of 1881. Be that as it may, the destructive work of the moth was observed in Central Park, New York City, in 1884, by Dr. E. B. Southwick, and in 1887 at Newark and in 1889 at Arlington and Orange, New Jersey. In 1894, Dr. Southwick pronounced it one of the worst insect pests attacking shade trees.[27]

In 1894, Smith stated[28] that Col. Nicholas Pike reported that the leopard moth occurred in Connecticut. It was soon noticed in cities near New York, though spreading much faster toward the northeast along the coast than in any other direction. In 1905, Dr. Felt[47] reported the pest at Kensico, N. Y., a point twenty-five miles north of New York City. The earliest Massachusetts record that we can find is that of a male taken by Mr. C. A. Frost[50] at Medford, July 1st, 1903. In 1907, Professors

C. H. and H. T. Fernald[49] called attention to the presence of the insect in the vicinity of Boston. In 1909 the senior author learned of its great destructiveness to the trees of Cambridge. Mr. E. H. Armstrong has observed its work at Taunton, Fall River and New Bedford, and Chapman[63] reports its presence at Concord, Lowell and Lawrence, as well as at many other places

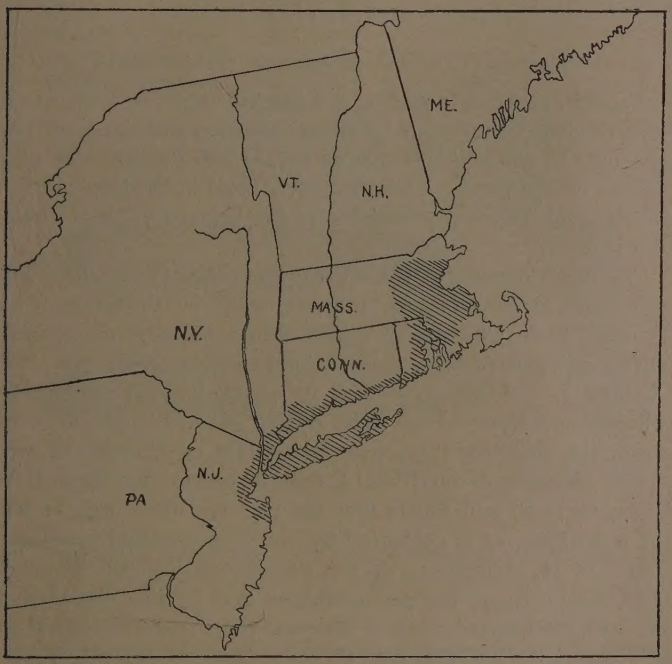


FIG. 2. Shaded area shows present distribution of the leopard moth in the northeastern states. Cape Cod may also be infested but we have no records to show it.

nearer Boston. Mr. Armstrong is authority for the report that the insect occurs at Providence, Newport, Westerly and East Greenwich, in Rhode Island.

The leopard moth is reported by Professor Smith[53] as occurring as far south as Long Branch, N. J., and Mr. Bartlett has seen it at Asbury. At the present time, as is shown by the map, Fig. 2, the insect occurs from Asbury, N. J., at least to the

vicinity of Lawrence, Mass., and in nearly every city along the coast, between these points, much damage has been done by it to shade trees. We have no records of the occurrence of the insect at points more than twenty-five miles inland. It is difficult to explain why it should spread so much more rapidly toward the northwest, along the coast, than in any other direction. Chapman questions[63] whether the infestation around Boston may not have resulted from a separate and later importation.

Distribution and Spread in Connecticut.

Though, as already stated, the leopard moth was reported to have reached Connecticut by 1894,[28] the first definite record that has come to our notice is that of Mr. H. M. Russell, now of the Bureau of Entomology, who formerly lived in Bridgeport, Conn. Mr. Russell collected specimens of the leopard moth at Bridgeport in 1901.[56]

The first Connecticut specimen in the collection of this station was taken in New Haven, July 1st, 1907, by Professor H. W. Foote of Yale University. Since then a number of specimens, chiefly males, have been taken around electric lights. Mr. A. B. Champlain, a former assistant in entomology at this station, collected and observed the males during 1910 and 1911, at several arc lights, including those near the station on Prospect street.

The photograph on Plate I was taken on the New Haven Green in 1908, and shows that the pest had then been at work for some time, as is evidenced by the dead terminal branches.

Mr. E. H. Armstrong of the Providence Forestry Company, Inc., has informed the senior author that he has observed the work of the leopard moth in New Haven, New London, Mystic and Stonington and that with the exception of Cambridge, Mass., he considers New Haven the worst infested spot that has come under his notice.

Mr. F. A. Bartlett of the H. L. Frost & Bartlett Company states in a letter that he has observed the work of the insect in practically every town and city along the Connecticut coast this year, and that it has been especially serious at Bridgeport and less so at Stamford and South Norwalk. He also saw a little of its work at Danbury, which is about twenty-five miles inland.

Mr. D. J. Caffrey, assistant in charge of the gypsy moth work, observed, in 1911, many trees showing the characteristic leopard moth injury at Wallingford, about twelve miles from the coast.

In September, 1910, the leopard moth was found infesting young apple trees in a nursery at New Canaan, Conn., the adult insect was reared from the larva, and a short account was published in the Journal of Economic Entomology[61] for June, 1911. This locality was less than ten miles from the coast. The insect was found again in the same field in September, 1911.

DESCRIPTION.

Adults.—Wing expanse from two and one-half to three inches in the female and about one and three-fourths inches in the male. Wings dirty white and semitransparent, with a yellow or brownish front margin to the fore wings and the same color extending along the principal veins. The wings are marked with metallic blue dots, as shown in the accompanying illustrations, Figure 1, and Plate VIII, a. The markings are much more

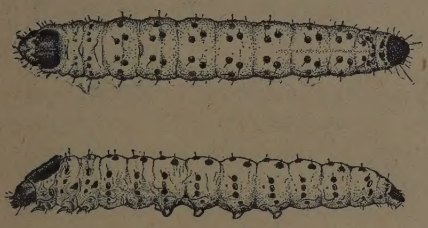


FIG. 3. Leopard moth caterpillar. Dorsal and lateral views, natural size.

FIG. 4. Pupa, natural size.

pronounced in the female than in the male, which sometimes has very faint dots. Color much brighter in the female. Thorax white or yellow dorsally, with six blue-black spots, three in a row on each side. Ventral side, black; abdomen, black, with more or less whitish pubescence, and the female has an extensile three-jointed ovipositor, by means of which eggs are laid under the edges of bark; legs, black; the second and third pairs of femora bearing whitish woolly hairs. The female has thread-like and the male feathery antennæ. The female is shown in Figure 1, and both sexes on Plate VIII, a.

Egg.—The eggs are about the size of a pinhead, or one-sixteenth of an inch long, oval, somewhat pointed, and salmon or orange-yellow in color. They are usually laid singly or in groups of two, three, or four each. Shown on Plate VIII, b.

Larva.—Length about two and one-fourth inches, dirty white, dull yellow, or flesh-colored, marked with dark brown or black tubercles, each bearing a short bristle. The fourth to the tenth segments inclusive bear two pairs of tubercles, the front pair being closer together than the rear

pair. The second, third, eleventh and twelfth segments have smaller tubercles arranged more nearly in transverse rows. Laterally, there is a row of brown tubercles just above and another row just below the spiracles. A second row of smaller tubercles may be seen on the bases of the legs and pro-legs. The large cervical shield and smaller anal shield are dark brown. Head, dark brown, with upper part of front lighter. Legs, light brown. The larva is shown in Figure 3, and on Plate VIII, c.

Pupa.—About one and one-half inches long, scarcely tapering, anal extremity, blunt; dark brown in color. On the proximal and distal margins of each abdominal segment there is dorsally a ridge consisting of a number of short, black spines or teeth, pointing backward. Similar spines or hooks, projecting forward, occur on the ventral surface of the posterior segment. Shown in Figure 4.

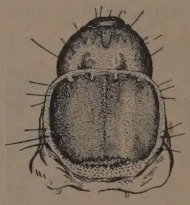


FIG. 5. Head and cervical shield of larva, much enlarged.

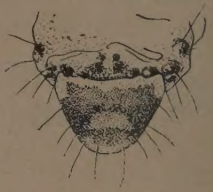


FIG. 6. Anal plate of larva, much enlarged.

All stages of the leopard moth are shown in the accompanying illustrations.

LIFE HISTORY AND INJURY.

Just as the manuscript of this bulletin was ready for the printer, a publication on the same subject by James W. Chapman,[63] and published by the Bussey Institution of Harvard University, came to hand. Mr. Chapman, by original observations, has made an important contribution to the habits and life history of this insect, and we have, therefore, revised several paragraphs in this bulletin, to include the chief results of Mr. Chapman's studies.

The adult moths appear during a period extending from May to September, according to the circular issued by the Bureau of Entomology.[56] In New Haven, however, by far the greater number are found during the early part of July, while specimens have been secured during late June and the first week in August. The male is much the smaller, and flies with ease, being attracted

by the electric lights. The female has a heavy body, and flies very little, preferring, if possible, to lay eggs on the same tree where she emerged from the pupa. For this reason, high trees, isolated, and one hundred feet or more away from others injured by the leopard moth, may remain uninfested for years, while continuous rows of trees with branches touching are soon infested throughout.

The moths eat nothing and live at the most but a few days, the male dying immediately after copulation, the female as soon as the eggs are laid. One female captured by the junior author lived three days.

The eggs are inserted in crevices in the bark, or beneath plates of bark, one to several in a place, usually in the higher branches of the tree. They may, however, be laid on larger branches or on the trunks of small trees. They are less than one-sixteenth of an inch in length, oval, and yellowish or salmon colored. Several observers, including the junior author, have found the eggs laid by females in confinement, in several masses, due, no doubt, to the unwillingness of the female to deposit them sooner than necessary under unsuitable conditions. Numbers of the borers, just hatched, were found, and in every case they were working singly, usually just above a bud or twig on one of the smaller branches. This, according to J. W. Chapman,[63] means that the new larvæ do not enter the branch at the place where they hatch, but crawl some distance to the smaller twigs. Although this is the rule, the junior author has found several which had entered branches two to five inches in diameter, taking advantage of crevices in the bark. Each female may deposit from 400 to 800 eggs.

The larvæ hatch within a few days (ten days, according to Mr. Walker[26]), being plentiful in the latter part of July, and immediately commence their destructive work, boring into the branches. A careful examination of the twigs of an infested tree will show a slight amount of the white, powdery sawdust expelled by each larva during the first few days after hatching. In a few days the character of the expelled frass changes to small cylindrical pellets, light golden or brown in color.

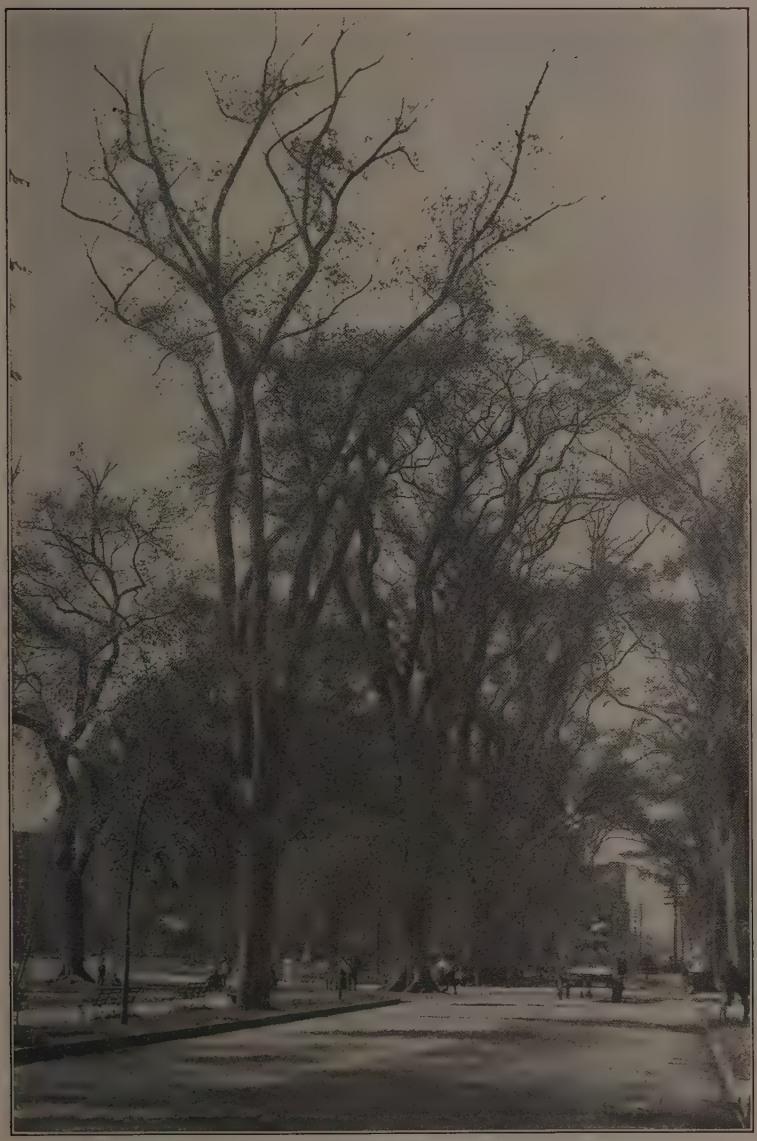
Several experiments made by Mr. J. W. Chapman[63] are of value in showing the activity of the newly-hatched larvæ. A number of these were placed at the base of a fresh lilac bush

and soon commenced to climb. On reaching the twigs, they were at once taken off and again placed at the base, when they would immediately commence climbing again. In this way four of those making the greatest progress had in four hours traveled distances varying from twenty-five to eighty feet.

Other experiments showed that some of the more recently hatched larvæ were able to crawl from fifty to one hundred feet on the ground, through grass and rubbish, while others nearly full-grown would move very little, but would protect themselves by spinning together small particles of sticks and dirt.

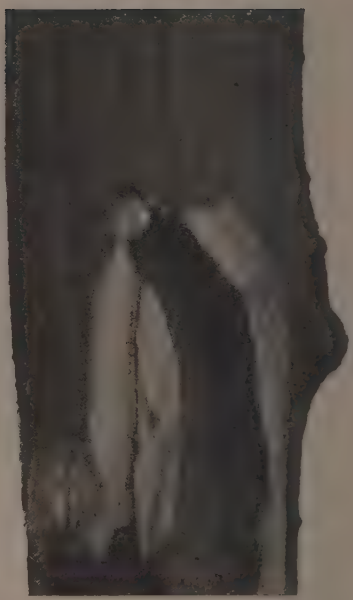
Growth is rapid, and the larvæ reach a length of about an inch by the end of the first season. The general tendency is for the insect to work upward from the hatching point, or from any opening made for expelling the frass. Small twigs are hollowed out, leaving little but a shell of bark, and small branches may be girdled, causing them to break off during a heavy rain. Where the young hatch in larger branches, the regular burrows are often varied by small, irregular patches eaten out of the inner bark. Branches too small, in a dying condition, or otherwise unsuitable, are vacated, the insect crawling on the outside of the bark and making a fresh entry on another and usually larger branch. A burrow may strike a knot or small branch, when, after going back several inches, the insect starts in a new direction. New outlets may be made, and the use of old ones discontinued from time to time. These outlets are always in some protected situation on the under side of a branch or in a crotch. They are kept covered with a closely woven silk web, this being broken and remade each time the frass is expelled. In one case the web was broken by the junior author and remade by the insect five times within an hour. This web certainly helps to conceal the hole, and may be used to keep out air, parasites, ants and other insects. Unlike the galleries of the sugar maple borer, those of the leopard moth are kept clear, all frass being removed as soon as a small pile has accumulated, and cement sidewalks under badly infested trees are often littered with the brownish pellets expelled from the burrows.

During the latter part of October the larvæ leave the outer wood and bore slanting holes upwards and into the wood two inches or more from the bark, where they remain in a dormant stage over winter. Sharp[74] cites Kalendar to the effect that the

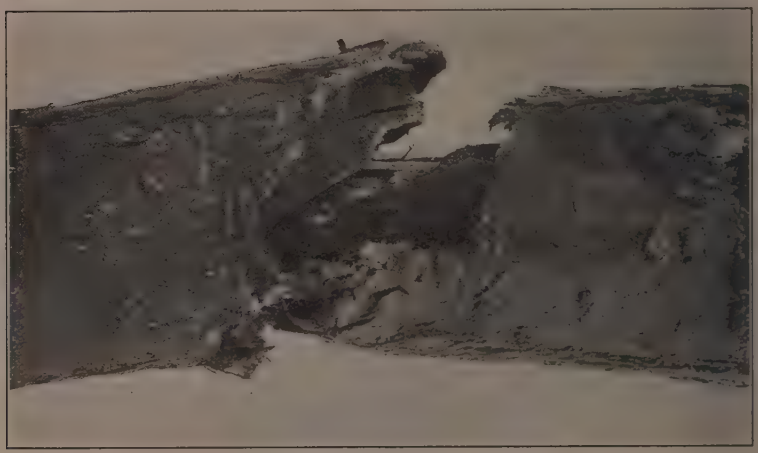


Trees injured by leopard moth show dead terminal branches. View on New Haven Green. Photo. loaned by Geo. Dudley Seymour.

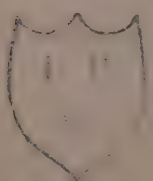
PLATE II.

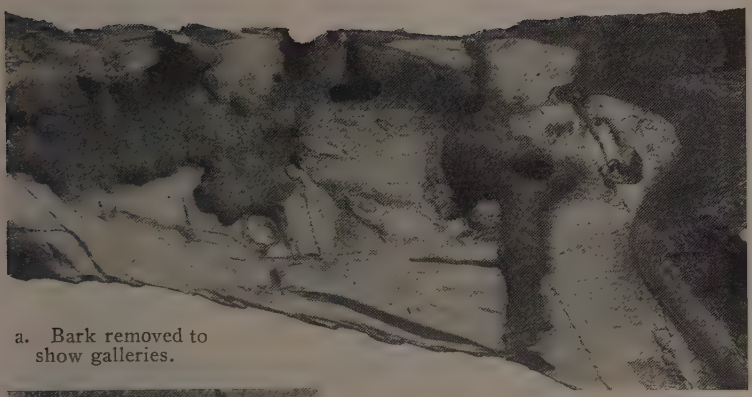


a. White web closing outlet; wood cut away to show burrow. Twice natural size.



b. Branch girdled and broken.



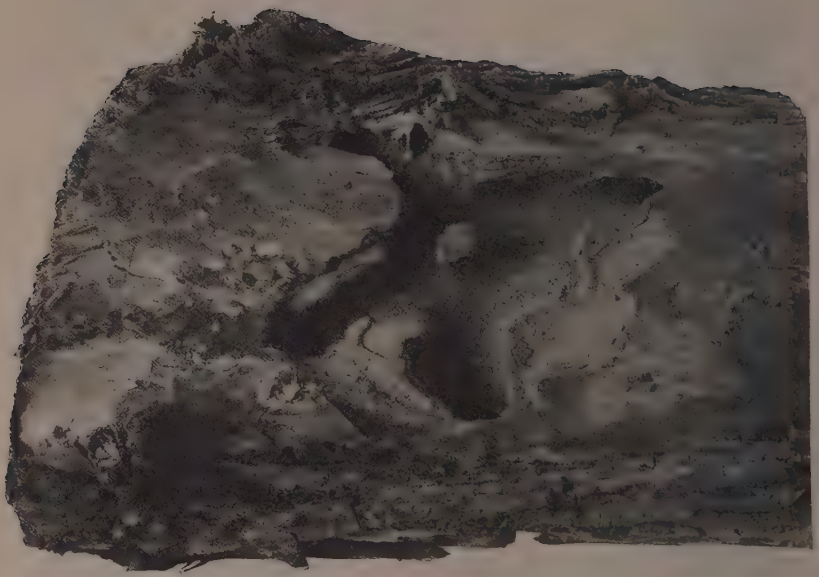


a. Bark removed to show galleries.

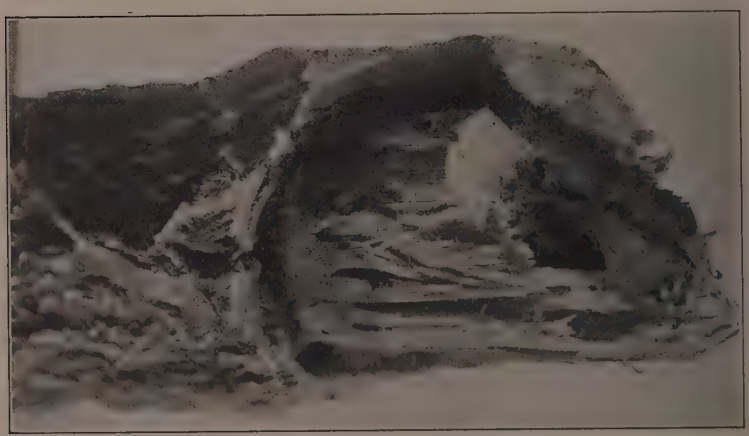
b. Wound on maple trunk beginning to heal. Pupa case above.

c. Winter resting place of larva. Natural size.

PLATE IV.

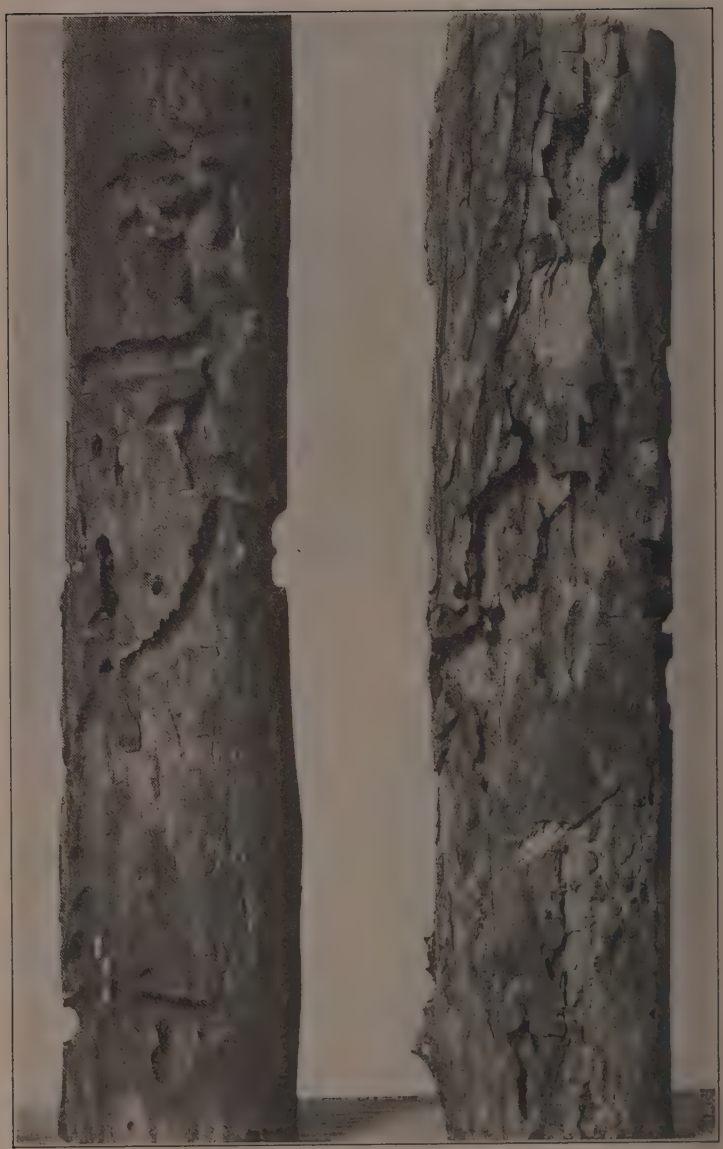


a. Elm branch showing galleries of the leopard moth larva.



b. Elm branch girdled by larva and broken.

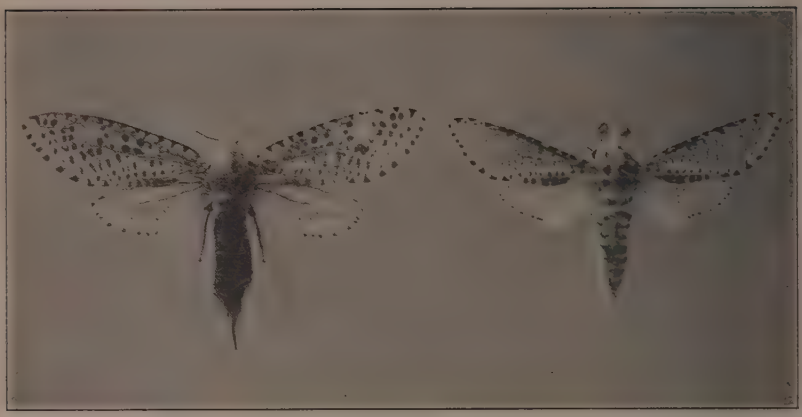
Appearance of galleries in large branches.



Dead branches with bark removed to show galleries.

I. B. E.

Male leopard moth reared from apple nursery stock.



a. Adult leopard moths, female at left. Natural size.

b. Eggs, greatly enlarged. Photo. loaned by J. W. Chapman.

c. Larva in its burrow. Natural size.

larva forms a temporary cocoon in which it passes a winter sleep before again feeding in the spring, but this is not the case in Connecticut, as Mr. Cromie has taken numbers of naked larvæ from the branches during winter.

The boring is continued in the same manner during the next summer, but the damage done is now much greater, both the insect and the branches attacked being larger. Branches four to eight inches in diameter may be entirely girdled, or large patches of wood may be eaten out. The wounds made the preceding year now show at their worst, the bark falling away, and ugly ridges being made where they have partially healed.

When fully grown, the larvæ are about two and one-fourth inches in length, and most of them do not enter the pupa state until the early part of the succeeding summer, when they are nearly two years old. The writers have reason to believe that some of those hatched early change to pupæ and complete the life cycle as those appearing latest during the next year. However, those passing the second winter continue active boring in the spring, changing to brownish pupæ in May or later. This is done in a small chamber within a few inches of where the larva has previously cut its way almost through the bark. It also further protects itself, before pupating, by a fine web placed between itself and the place of exit. In from four to six weeks the pupa cuts through the bark and, by means of protuberances on the abdominal segments, wriggles itself partially out of the hole, where it leaves the shell or pupa case after it flies, as may be seen on Plates III, b, and VII.

As shown before, this insect attacks to some extent nearly every tree, native or exotic, growing in this region, except evergreens, so that a full list is not necessary. However, in New Haven the American elm is one of the kinds most severely attacked, while, owing to its dark, plated bark, even on the smaller branches, the insects in it are very hard to detect. With it, in amount of injury done, may be classed the silver maple and the sycamore maple. Other common species often seriously injured are ash, English elm, basswood or linden, tulip, sugar, red and Norway maples, poplar and horsechestnut. The honey locust, sycamore, sweet gum, and oak seem much less liable to attack, in many cases, in New Haven, remaining uninjured, although standing in rows with affected elms.

Natural Enemies and Checks.

In this country no parasites have been recorded that hold the leopard moth in check. In Europe a chalcidid parasite of the subfamily Encyrtinae, *Litomastix* (*Copidosoma*) *truncatella* Dalm., has been reared by E. A. Fitch. (Entomological Magazine, Vol. XVIII, p. 116.) This and an ichneumonid, *Schreineria zeuzeræ* Schrein (not Ashm.), are mentioned in a letter to Mr. Cromie from the American Consul-General at Berlin, the information being received by him from the Kaiserliche Biologische Anstalt für Land-und Forstwirtschaft in Dahlem-bei-Steglitz. The former, *L. truncatella,* is probably the same as was reared in this country from the cabbage looper, *Plusia brassicæ* Riley. (Rept. of Ent. U. S. Dept. Agr. 1883, p. 121.)

An examination of hundreds of the caterpillars and pupæ, as well as the burrows made by them, shows that the leopard moth is remarkably free from natural enemies of all kinds. In no case was there evidence of either parasitic or predaceous insects. Dr. L. O. Howard, who has given some attention to the subject, has not found that any effective parasitic check exists even in Europe, though he has promised to bring to America the species known to occur there. Mr. Cromie found in New Haven a caterpillar dead in its burrow and full of small maggots, but these proved to be a Phorid fly, *Aphiochæta nigriceps* Loew., which probably did not attack the borer until after it had died from some other cause. This was the only indication found of an insect being destroyed while in its burrow. All pupæ, the stage generally exhibiting parasitism, seemed to have developed properly. Undoubtedly some check to the insect must exist before the burrow is developed, because of the small number of burrows found as compared with the large number (several hundred) of eggs, laid by each female. Either the female is unable to deposit any large number of her eggs in proper situations, and they thus fail to hatch, or the eggs themselves are largely eaten by the birds or insects found in cities. The writers have noticed that English sparrows search for and apparently find food on elms infested by the leopard moth in July, when the eggs should be plentiful and the young borers just hatching, but their prey might have been other insects. In many cases small holes, barely started by newly hatched larvæ, were found vacant, indicating that birds had secured the insects before they were able to enter the wood.

As the leopard moth is a pest chiefly of cities and towns, it is thought that certain birds, especially woodpeckers, assist in checking it, especially in the country districts. The habits of the moths in flying about electric lights would lead one to expect that many of them might be eaten by bats and night-flying birds. It is also believed that sparrows sometimes may feed upon the eggs or young larvæ. Smith states[78] that the leopard moth is a serious pest only where the English sparrow has driven away the native birds.

No other explanation can be given of the scarcity of the leopard moth in the country, adjacent to infested towns, except the presence of insectivorous birds. This tendency of the insect to become a pest only within cities and towns is noted by several English, French and German writers, as well as in this country. Mr. James Walker of Newark, N. J., states that infested elms placed in a nursery outside the city limits of Newark were rid of the larvæ by woodpeckers. This coincides with a statement made by P. Lesne,[79] who mentions having seen in Northern Algeria numerous woodpecker holes ending in the burrows of the leopard moth. While traveling from one branch to another, a habit of this insect, it is exposed to the attacks of birds. Mr. J. W. Chapman[63] also cites evidence of squirrels in the Boston parks chewing the smaller branches to secure the larvæ, which they relish.

Especially in early summer, numbers of small girdled branches in full leaf are broken off by storms. Nearly all of these contain the caterpillar which has done the girdling, and the branch soon wilts and dies. Though most of the larvæ desert the branch within two or three days after it falls, the junior author has found several of these shrunken and in a dying condition on the branch, showing that the insect cannot sustain life on the dead wood. It is also evident that very few of those which leave the branch are able to again find and climb a large tree. On city streets these branches are usually gathered at once and destroyed because of their hindrance to traffic. In parks it is even more necessary that this should be done, as here the insects can easily leave the fallen branches and enter shrubbery or small trees.

Remedial Treatment.

In view of the protected life led by this insect, treatment is especially difficult. Tunneling under the bark during the greater

part of its life, it is not affected by arsenical or contact sprays. The protracted period during which it may appear as a moth hinders effective action against the adult. Isolated trees recently infested, and small trees with smooth bark, can be saved by a thorough inspection two or three times a year, followed by the removal of badly infested branches and the destruction of larvæ found, either by the injection of carbon disulphide (bisulphide) into their burrows or the insertion of a hooked wire to draw them out. Large trees badly infested should be cut down at once.

Unfortunately, this insect lives so concealed a life as to attract little attention until it is well distributed in a town or city and serious damage has been done to the trees. Where not already present, all planting stock should be bought from nurseries free from this pest,—probably in a district not yet affected. A careful watch must be kept for its first appearance, when, because of the inability of the female to make long flights, the removal of the trees for a couple of hundred feet around the affected section will form a quarantine that will greatly help to keep it in check. Special attention can then be given to all trees in and close to the affected area. Most citizens are averse to having trees removed from in front of their property until they are very far gone, but stern measures are necessary in preventing the spread of this insect.

Electric Lights. The moths are attracted by the strong arc lights used for street lighting, and numbers of them, largely males, could be secured in the flying season by sending men around to collect them from nine to twelve o'clock at night, or by the payment of a small bounty to boys, according to the quantity collected. This method of check, especially where females are secured, is of immense value, as it is much easier to prevent eggs being laid than to find the larvæ, which would otherwise hatch.

Mr. J. W. Chapman,[63] during the month of July, had placed in the Harvard College yard three six ampere arc lights, without globes or reflectors. About twelve inches beneath each light a pan three inches deep and twenty-four inches in diameter was suspended by wires. The pan was then half filled with water, with a thin film of kerosene on top. These lights were run as traps during the first two weeks of July, the insects being

attracted to the lights and then falling into the pan and being killed by the oil. In this way 279 male and 58 female moths were taken. Undoubtedly if the traps had been placed during June, when the moths first began to fly, a correspondingly larger number would have been taken.

Removal of Affected Branches. Trees badly affected are best removed, as the pruning of large numbers of branches leaves only mutilated specimens not worth the cost of the repeated inspection and treatment required.

Pruning should be done while the tree is in foliage, preferably twice a year, once in spring and once in late summer. The number, size and color of the leaves is the best guide as to affected branches. The tendency is not to remove many of these, which, if left, will probably die later in the season, or at least harbor numbers of eggs and of the young larvæ whose work does not yet show. All dead branches should be removed at a point well below the beginning of the green wood, so as to be more likely to secure the insects doing the damage. Branches containing small leaves, leaves thin or yellowish in color, or those where the leaves are few and scattered, are sure to be infested and should be removed.

Inspection, and Destruction of Larvæ. On large numbers of trees over fifty feet in height, the expense of this method is prohibitive, and the difficulty of locating the insects renders it impracticable. Especially is this so with elms of even smaller size, because of the rough, scaly bark on all but the smallest twigs. Also on such trees the branches are very numerous, long, slender and horizontal, making climbing in some places impossible.

To find out how successfully this method could be applied to large elms, the junior author selected several badly infested ones, sixty to eighty feet high, and had two of his best climbers treat them under his personal inspection, without limiting them as to time. Then live branches which had thus been carefully examined were cut from the tree and the bark peeled with a draw knife, exposing all leopard moth galleries. Less than twenty-five per cent. of the larvæ on the infested branches had been secured while on the tree. Also, Mr. Chapman, in describing the experiments in Harvard College yard, states that previous to placing the trap lamps, in which over three hundred moths were secured, "the

yard had been patrolled since early spring by three men, who spent their entire time searching out and destroying the larvæ and pupæ of the moth."[63] On smaller trees, in New Haven, especially of species with smooth bark, it was found possible, by a thorough inspection, to secure practically all of the older larvæ.

In East Orange, New Jersey, where there are few elms, and the trees are, as a rule, from ten to fifty feet in height, the following method, carefully applied for three years, has placed the leopard moth under control:—Gangs of men, trained to the work, in August and September of each year look on the ground and sidewalk under every tree for the piles of brownish pellets and sawdust dropped by the borers. Carefully spotting the branch over each pile, the man climbs the tree and, if experienced, can locate nearly every hole, which, at that time, is covered by the silk web, when the insect is either secured with a wire, or carbon disulphide is injected from a small oilcan, and the hole stuffed with putty or soap.

Although the burrows are usually well cleared of frass, allowing the fumes of the carbon disulphide free access, there may be other outlets to the burrow, so the method of securing the insect with a wire is surer. A piece of No. 16, soft, steel wire is used, one end being bent into a very small hook, and sharpened from time to time by cutting the end of the hook in a slanting direction with a pair of linesman's pliers. Often the insect cannot be reached without cutting the burrow open for some distance with a stout jackknife, but this is easily done, as there is only the bark to cut through, and the real injury is not increased. If the branch is found to be nearly girdled, it had better be cut off.

In this way the larger larvæ (those in their second summer), which, of course, are found in the larger branches, are destroyed, preventing the laying of eggs the following summer. The same method is followed out the succeeding fall, when the younger larvæ, which, by this time, have grown large and come down to the larger branches, are also procured.

In high trees, the wind so scatters the falling pellets as to make it impossible to ascertain from their location on the ground the number or location of the insects in the tree.

Disposal of Infested Wood. It is very often not convenient in large towns or cities to burn the infested wood secured after

storms or by the trimming and removal of trees. Often the wood could be utilized by people in the vicinity in which it is collected, or it may be left at some nearby public dump.

During the spring of 1911, the junior writer secured a number of branches broken off by storms, and containing larvæ. The borers remained in the wood for a few days, until the leaves began to wilt and the wood commenced to dry, when most of them left the branches. Unable, however, to find new green branches to enter, they soon grew thin and died. Mr. Chapman,[63] with older larvæ, secured later in the season, found that the borers were able to exist during the winter in wood removed from the tree and to emerge as moths the following spring. Unless the wood is to be used immediately, or placed in a dump where they will soon be buried by ashes, dirt, etc., branches secured by trimming or blown down by storms should be burned.

Care in Planting. Until some effective check is found for this insect, it is best not to plant too heavily those species of trees which are especially liable to attack. Species with short, strong branches, covered with smooth bark, should be given the preference, being more easily inspected and taken care of by the methods just given. Planting the young trees a greater distance apart than usual, makes it more difficult for the insect to spread from one tree to another.

In this connection, it might be said that, in Brooklyn, one of the first cities in America to be infested, Mr. J. J. Levison reports the insect as far less injurious than formerly, although no direct measures have been taken for its control, and the junior author has seen there rows of elms and other trees almost untouched by this insect.

Care of Trees. Although trees in good health are not immune to attack, many authorities claim that they are less liable to injury than unthrifty trees. It is certain that in New Haven the greatest damage by the leopard moth has been done to trees on streets where the conditions are most adverse to tree life, and at least wounds are more easily healed, and recovery after attack is surer, where the trees are kept in a thrifty condition.

BIBLIOGRAPHY.

AMERICAN.

1 1862 Morris, J. G. Synopsis Lepidoptera North America (Smithsonian miscellanous collections), p. 125 (N. A.).

2 1864 Packard, A. S. Proceedings Philadelphia Entomological Society, iii, p. 390 (N. A.).

3 1882 Doll, J. Papilio, vol. ii, p. 34.

4 1888 Graef, E. L. Entomologica Americana, vol. iv, p. 162.

5 1889 Angelman, J. B. Entomologica Americana, vol. v, p. 28 (Newark, 1887).

6 Grote, A. R. Entomologica Americana, vol. v, p. 7.

7 Smith, J. B. Report New Jersey Agricultural Experiment Station, p. 279.

8 1890 Chittenden, F. H. Entomologica Americana, vol. vi, p. 218 (note re distribution).

9 Machesney, C. P. Entomologica Americana, vol. vi, p. 31 (Arlington).

10 Riley, C. V. and Howard, L. O. Insect Life, vol. ii, p. 290 (note re Smith's article in Garden and Forest).

11 Smith, J. B. Insect Life, vol. ii, p. 386 (correction of preceding).

12 Smith, J. B. Garden and Forest, vol. iii, p. 30.

13 1891 Southwick, E. B. Report Entomological Society of Ontario, xxii, p. 78 (recent destruction in New York).

14 Smith, J. B., et al. Canadian Entomologist, vol. xxiii, p. 221 (discussion at meeting).

15 1892 Lintner, J. A. Report New York State Entomologist, vol. ix, p. 426 (brief acct.).

16 Pike, N. Insect Life, vol. iv, p. 317 (illus. article).

17 Riley, C. V. and Howard, L. O. Insect Life, vol. iv, p. 77-8 (notes of correction).

18 Smith, J. B. Canadian Entomologist, vol. xxiv, p. 136 (remarks on Walker's citation; doubts identity).

19 Smith, J. B. Entomological News, vol. iii, p. 206 (note).

20 Southwick, E. B. Insect Life, vol. iv, p. 61 (note).

21 1893 Riley, C. V. and Howard, L. O. Insect Life, vol. v, p. 204 (note of correction).

22 1894 Neumoegen, B. and Dyar, H. G. Journal New York Entomological Society, vol. ii, p. 160 (descr. *pyrina*).

23 Riley, C. V. and Howard, L. O. Insect Life, vol. vi, p. 40 (note on number of eggs).

24 Riley, C. V. and Howard, L. O. Insect Life, vol. vi, p. 377 (note on habits).

25 Smith, J. B. New Jersey Agricultural Experiment Station, Bull. 103, p. 9.

26 1894 Smith, J. B. Report New Jersey Agricultural Experiment Station, p. 519 (good acct.).

27 Southwick, E. B. Report Entomological Society Ontario, xxv, p. 107 (recent destruction in New York).

28 1895 Smith, J. B. Insect Life, vol. vii, p. 138 (report by Pike from Connecticut).

29 Southwick, E. B. Insect Life, vol. vii, p. 136 (mention of injury).

30 1896 Smith, J. B. Economic Entomology, p. 287 (brief illus. acct.).

31 1897 Smith, J. B. Report New Jersey Agricultural Experiment Station, p. 397 (mention).

32 Webster, F. M. Ohio Agricultural Experiment Station Bull. 77, p. 48 (illus. acct.).

33 1898 Beutenmüller, Wm. Bombycine Moths of Vicinity of New York, Bull. Amer. Museum Natural History, vol. x, p. 445 (descr. and note, illus.).

34 Felt, E. P. Report of Commissioners of Fisheries, Game and Forests, iv, p. 16 (illus. acct.).

35 Smith, J. B. Report New Jersey Agricultural Experiment Station, p. 385 (mention).

36 1899 Felt, E. P. New York State Museum, vol. vi, No. 27, p. 50 (brief acct., illus.).

37 Smith, J. B. Insects of New Jersey, Suppl. Report N. J. Board of Agriculture, p. 497 (brief acct., illus.).

38 Smith, J. B. Report New Jersey Agricultural Experiment Station, p. 445 (mention).

39 1900 Britton, W. E., et al. Connecticut Agricultural Experiment Station Bull. 131, p. 13 (mention).

40 Felt, E. P. New York State Museum, vol. viii, No. 37, p. 23 (note, illus.).

41 MacCartney, B. F. Report Pennsylvania Department of Agriculture, p. 94 (brief illus. acct.).

42 1901 Felt, E. P. Report New York State Entomologist, xvii, p. 745 (occurrence at Newark, N. Y.).

43 Smith, J. B. Report New Jersey Agricultural Experiment Station, p. 480 (mention; not so destructive).

44 1903 Gibson, A. Report Entomological Society Ontario, xxxiv, p. 61 (mention).

45 Holland, W. J. Moth Book, p. 376 (illus. acct.).

46 1904 Doll, J. Entomological News, vol. xv, p. 110.

47 1905 Felt, E. P. Insects Affecting Park and Woodland Trees, vol. i, p. 75 (full acct., illus.).

48 Smith, J. B. New Jersey Agricultural Experiment Station Bull. 181, p. 29 (brief acct.).

49 1907 Fernald, C. H. and H. T. Report Massachusetts Agricultural Experiment Station, p. 155 (short note, damage near Boston).

50 1907 Frost, C. A. Psyche, vol. xiv, p. 63 (appearance in Mass. in 1903).
51 1908 Britton, W. E. Report Connecticut Agricultural Experiment Station, p. 847 (presence in Conn.).
52 Smith, J. B. Report New Jersey Forest Commission, p. 89.
53 Smith, J. B. Report New Jersey Agricultural Experiment Station, p. 315 (mention).
54 1909 Britton, W. E. Report Connecticut Agricultural Experiment Station, p. 356 (acct.).
55 Fernald, C. H. and H. T. Report Massachusetts Agricultural Experiment Station, part 2, p. 72 (mention).
56 Howard, L. O. and Chittenden, F. H. Bureau of Entomology Circular 109 (full acct., illus.).
57 Reiff, Wm. Psyche, vol. xvi, p. 28 (larva in oak).
58 Smith, J. B. Insects of New Jersey, rev. ed., Report New Jersey State Museum, p. 516 (illus. acct.).
59 1910 Britton, W. E. Journal Economic Entomology, vol. iii, p. 436 (mention).
60 Britton, W. E. Report Connecticut Agricultural Experiment Station, p. 664 (mention).
61 1911 Britton, W. E. Journal Economic Entomology, vol. iv, p. 298 (on nursery stock, illus.).
62 Solotaroff, Wm. Shade Trees in Towns and Cities, p. 182 (illus. acct.).
63 Chapman, J. W. The Leopard Moth and other Insects Injurious to Shade Trees in the Vicinity of Boston. Bussey Institution, Harvard University (full acct.).

EUROPEAN.

The authors have made no attempt to give a complete list of European writings on the leopard moth. A few are here cited from works on hand to indicate the status of the insect as a pest in Europe.

64 1840 Kollar, V. Insects Injurious to Gardeners, Farmers, etc., p. 207 (brief acct.).
65 1854-66 Walker, F. List of Specimens of Lepidopterous Insects in the Collection of the British Museum.
66 1873 Wood, J. G. Insects at Home, p. 428 (brief illus. acct.).
67 1874 Kaltenbach, J. H. Die Pflanzenfeinde, pp. 73, 184, 429, 548, 774 (mention of food plants).
68 1890 Ormerod, E. A. Manual of Injurious Insects, p. 320 (brief illus. acct.).
69 1892 Ormerod, E. A. Text Book of Agricultural Entomology, p. 132 (mention, illus.).
70 1895 Judeich (J. F.)-Nitsche (H.) Forstinsektenkunde, p. 773 (illus. acct.).

71 1895 Schlich, Wm. Manual of Forestry, vol. iv, p. 264 (descr. note about injury and food plants).
72 1897 Eckstein, K. Forstliche Zoölogie, p. 479 (brief acct.).
73 1898 Ormerod, E. A. Hand Book of Orchard and Bush Fruit Insects, p. 132 (illus. acct.).
74 1901 Sharp, D. Cambridge Natural History, vol. vi, p. 395 (mention).
75 1903 Henry, E. Atlas d'Entomologie Forestiere, p. 29 (illus.).
76 1904 Theobald, F. V. Report on Economic Zoölogy, ii, p. 30 (note).
77 1905 MacDougall, R. S. Journal Board of Agriculture (London), 12, No. 2, p. 115. Abstract Expr. Sta. Record, vol. xvii, p. 1092 (remedial treatment).
78 1908 Gillanders, A. T. Forest Entomology, p. 247 (brief illus. acct.; sycamore, hawthorn).
79 Lesne, P. Compt. Rend. Academy Science (Paris) 146, p. 493 (great damage to cork oak in Algeria).
80 Theobald, F. V. Report on Economic Zoölogy, p. 24 (brief note).
81 1909 South, R. The Moths of the British Isles, p. 348.
82 Theobald, F. V. Insect Pests of Fruit, p. 46 (illus. acct.).
83 Theobald, F. V. Report on Economic Zoölogy, p. 29 (brief note, illus.).
84 1911 Lesne, P. Compt. Rend. Academy Science, 152, p. 1269. Abstract Expt. Sta. Record, vol. xxv, p. 464 (larvæ in cork oak).

SUMMARY.

The leopard moth occurs in Europe and parts of Asia and Africa, and was probably accidentally introduced into this country from Europe more than thirty years ago, being first noticed at Hoboken, N. J., and later spreading toward the north and east along the coast. At the present time it is found from Asbury, N. J., to Lawrence, Mass., but has not been taken more than twenty-five miles inland.

The larvæ or caterpillars cause great damage to nearly all kinds of shade trees by boring in the branches just under the bark and cutting large galleries, often across the grain, thus girdling them. Dead branches extending above the mass of foliage in the tree-tops are a sign of attack, and many twigs will be broken off or wither during the summer. The pest has been especially destructive to elm and silver maple trees in the coast cities and towns of Connecticut, but is not so abundant in the open country. It has caused much damage also in the cities of New Jersey, New York City, Providence, Cambridge and Boston.

The adult moths are dirty white, with semitransparent wings marked with metallic blue dots. These have an expanse of one and three-fourths inches in the male to two and one-half inches in the female. The larva is yellow or dirty white, marked with brown or black dots, and about two inches long. See illustrations.

The moths appear about July 1st, the males being very common around electric lights, and the females lay eggs singly or in groups of two, three or four, in the crevices of the bark or near the buds. The larvæ, hatching in a few days, begin to tunnel in the twigs, and by the end of the season are about one inch in length. They leave the small branches and crawl over the bark to enter larger ones, cutting large galleries in them and expelling the frass through round holes, which they soon close with silk webs. During October the borers go deeper into the wood, and remain through the winter two inches or more beneath the bark. They pupate in their burrows the second spring, and before the moth emerges the pupa works itself partly out of the opening, and the adult flies away, leaving the empty case protruding from the burrow.

There are few natural checks, only one parasite being known in this country and four in Europe. It is believed, however, that certain birds, especially woodpeckers, prevent the spread of the leopard moth in the open country. Many larvæ are doubtless killed by the breaking off of the branches, which in cities are carted away and destroyed.

Removing infested branches; injecting carbon disulphide (bisulphide) into the burrows, and stopping the opening; probing with a hooked wire for the larva; are some of the methods of control.

Planting species of trees not badly infested, like oaks, honey locust and sycamore, and especially those kinds that do not grow very large, and have a smooth bark; placing trees further apart, so that the larvæ cannot easily crawl from one to the other; and keeping the trees well nourished and vigorous, are the chief preventive measures.